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Determination of gas temperature in cathode fall of the self-sustained normal atmospheric pressure dc glow discharge

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The result of gas temperature measurements in cathode region of atmospheric pressure glow discharge in helium are presented. Temperature was determined using molecular bands of the first negative system of nitrogen (0,1) and OH ($A^2\Sigma^+$-$X^2\Pi_i$) (0,0) band. The obtained results are compared with calculated one using one-dimensional model of the cathode fall taking into account the volumetric heat generation.

1.Introduction

Gas temperature is one of main characteristic of a discharge gases, as it determines gas density and, as consequence, other discharge parameters. In [1] were determined main parameters of cathode fall, namely, the electric field profile, cathode fall thickness, current density, heat flux to the cathode. Gas temperature in mentioned work was measured only in negative glow. The aim of present investigation is a reception of the temperature distribution in cathode fall of the self-sustained normal atmospheric pressure glow discharge in helium.

2. Experimental

The self-sustained normal atmospheric pressure dc glow discharge was created in the pressurized chamber between two electrodes: the weakly rounded tungsten anode (diameter 6 mm), and flat circular steel cathode (diameter 30 mm) [1]. Interelectrode gap was about 4 mm. Experiment was fulfilled at discharge current of 1 Ampere. The impurities concentration in helium flow (H_2, N_2, O_2, Ar, CO_2, CO, Ne, H_2O) wasn't exceeding 0.02 %. The intensive water cooling of cathode was ensured due to its special design.

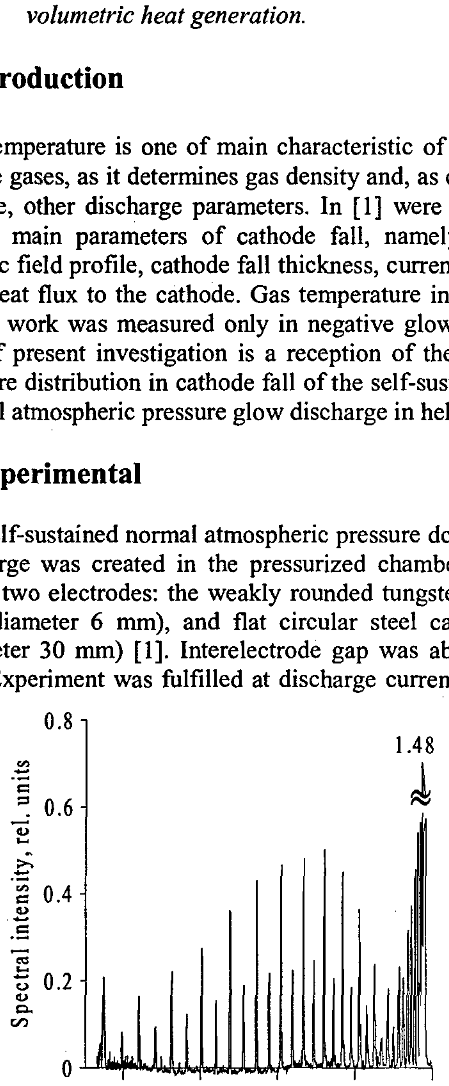

Fig. 1. Spectrum of the N_2^+ (0,1) band

The enhanced image of glow discharge using two objectives was focused onto entrance slit of the scanning 0.5-meter double diffraction monochromator of high resolution MDD500x2. At diffraction gratings with 1800 line per millimeter the inverse linear dispersion is 0.52 nm/mm. Band spectra of the (0,1) N_2^+ and (0,0) OH used for gas temperature determination are shown in fig. 1 and 2. At that the separate spectral lines have Gaussian profiles with halfwidth about 0.0065 nm.

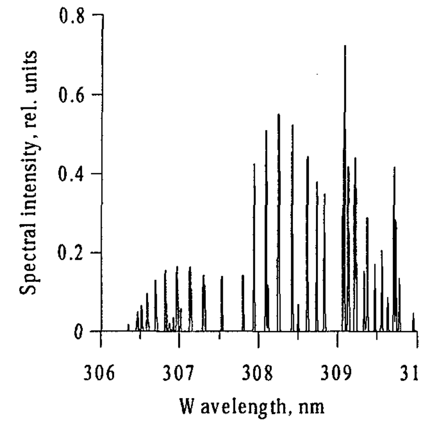

Fig. 2. Spectrum of the OH (0,0) band

3. Evaluation of gas temperature

The method of the relative rotational line intensity of molecular gases was used at determination of gas temperature [2]. Band of (0,1) of $N_2^+(B^2\Sigma_u^+ - X^2\Sigma_g^+)$ was chosen because it is free from superposition with other spectral lines. The rotational line of R-branch with N'>6 are used only. The necessary wavelengths for identification of rotational lines were calculated according [3].

Intensity of a doubling of rotational lines of R–branch at presence of boltzmann equilibrium is defined as

$$I_{N'} = \mathrm{const}\nu^4_{N'N''} S_{N'} g_{N'} (2N'+1)\exp\left\{-\frac{hcF(N')}{kT}\right\},$$

where $\nu_{N'N''}$ – frequency of optical transition; $g_{N'}$ – statistical weight caused by nuclear spin ($g_{N'}$ = 1 for even number N' and $g_{N'}$ = 2 for odd number N'); F(N') – magnitude of rotational term of the excited electron state; S_N=N'/(2N'+1) – Hönl-London factor of R–branch convolute on doubling line structure [4]. To h convolute on doubling line structure [4]. To determine the temperature using experimental spectra a graph of dependence $\ln(I_{N'}/G_{N'})$ against the rotational term energies, where $I_{N'}$ – measured intensity of doubling, and $G_{N'} = v^4_{N'} S_{N'} g_{N'} (2N'+1)$. The line doubling $\Delta_{N'}$ is increased while number N′ is increased and becomes equal 0.0053 nm at N′=21. Therefore, at determination of the experimental values $I_{N'}$ the profile change of doubling structure against the rotational line number was taken into account. In case of linear dependence of $\ln(I_{N'}/G_{N'})$ on F(N') it can talk about boltzmann distribution of population of molecule levels N′. At that the angle of regression slope will determine the rotational temperature.

Intensities of rotational lines of hydroxyl molecule at presents of boltzmann equilibrium is as follow

$$I_{BN'} = \mathrm{const}\, v_{BN'} A_{BN'} (2J' + 1) \exp\left\{ -\frac{hcF(N')}{kT} \right\},$$

where B – branch number, $v_{BN''}$ – frequency of optical transition, $A_{BN'}$ – Einstein's coefficient of spontaneous emission, J – full angular moment, F(N') – magnitude of rotational term of excited electron state. Values of the level energies and Einstein coefficients was taken from [5, 6]. As consequence, gas temperature is determined on line slope pictured the dependence $\ln[I_{BN'}/v_{BN'}A_{BN'}(2J+1)]$ on F(N′).

4. Results and discussion

The atmospheric pressure glow discharge is characterized the small dimensions of cathode regions and high heat release. As it is shown in [1], the cathode fall thickness is about 70 μm and maximal electric field

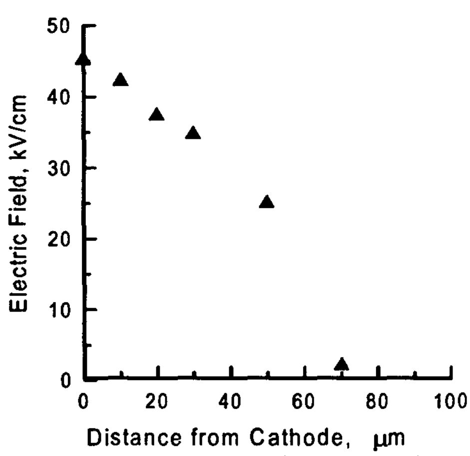

Fig. 3. Axial distribution of the electric field strength

strength ~45 kV/cm. Axial distribution of electric field in cathode fall is shown in fig. 3. Large quantity of heat generation in this narrow region takes place. Heat rejection from cathode fall is carried through the water-cooled cathode.

In fig. 4. the gas temperature determined in cathode fall using both the N_2^+ and OH bands is presented. As it seen, the values of temperatures in end of cathode fall (>70 μm) are in reasonable agreement. However these temperatures differ close cathode surface. Difference is

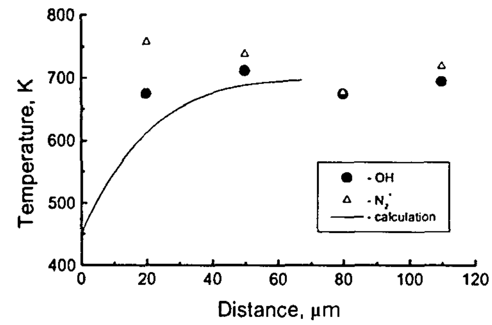

Fig. 4. Temperature distribution in cathode fall.

about 100 K and is more then experimental error. High temperature value obtained using the N_2^+ band, in our opinion, is explained by a acceleration of N_2^+-ions in strong electric field close cathode surface.

Calculated temperature distribution obtained using the model of cathode fall developed by Baranov-Smirnov [7] is pictured in fig. 4 (solid curve). Good correspondence of calculated temperature to measured one using the OH band is observed at distances more then 20 μm. Sharp decrease of gas temperature close cathode we can't resolve because the spatial resolution of our optical system is about 25 μm.

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5. References

[1] V.I. Arkhipenko, S.M .Zgirouski, A.A. Kirillov, L.V. Simonchik, *Plasma Phys. Reports* 28 (2002) 930.

[2] V.N. Ochkin, S.Yu. Savinov, N.N.Sobolev, *Trudy PhIAN* 157 (1985) 6.

[3] K.A. Dick, W. Benesch, H.M. Crosswhite, S.G. Tilford, R.A. Gottscho and B.W. Field , *J. Molec. Spectr.* 69 (1978) 95.

[4] G. Herzberg, *Molecular spectra and molecular structure. 1. Spectra of diatomic molecules,* N.Y.: D. van Nostrand (1951).

[5] J.A. Coxon, *Can. J. of Phys.* 58 (1980) 933.

[6] I.L. Chidsey, D.R. Crosley, *J. Quant. Spectrosc. Radiat. Transfe* 23 (1980) 187.

[7] G.A. Baranov, S.A. Smirnov, *Techn. Fiz.* 44 (1999) 1305.